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THE MINERAL INDUSTRY OF  
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WAR PERIOD.

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NICKEL.

(1913-1919.)

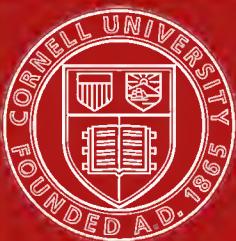


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## PREFACE.

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The following digest of statistical and technical information relative to the production of Nickel will form a part of the volume or volumes on the Mineral Resources of the British Empire and Foreign Countries constituting the Annual Mineral Conspectus of the Bureau.

Although nominally covering only the period of seven years ended 31st December, 1919, the digest will be found to contain more recent statistical and other information relative to the British Empire and to certain of the more important foreign countries.

In this, the first year of publication, an effort has been made to fill in, as far as possible, the hiatus due to the war in the publications relating to mining and metallurgical statistics. Labour, health and safety statistics have been omitted owing to the difficulty involved in procuring reliable information for the war period, but in future issues these statistics will be included in respect of each year. Resort will also be had to graphical representation of statistics of production, consumption, costs and prices.

The weights are expressed in long tons, that is to say, the British statute ton of 2,240 lb., and values in pounds, shillings and pence at par rates of exchange.

(Signed)      R. A. S. REDMAYNE,  
*Chairman of Governors.*

2, Queen Anne's Gate Buildings,  
London, S.W.1.

August, 1922.

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## GENERAL.

The nickel minerals of chief economic importance are nickeliferous pyrrhotite (magnetic sulphide of iron with varying amounts of nickel), pentlandite (sulphide of nickel and iron), garnierite (hydrated silicate of magnesium and nickel), and niccolite (arsenide of nickel).

Other nickel minerals which may be mentioned are chloanthite (arsenide of nickel), gersdorffite (sulpharsenide of nickel), zaratite (hydrated carbonate of nickel), and annabergite (hydrated arsenate of nickel).

Pentlandite is by far the most important nickel mineral. It is weakly magnetic, pale bronze-yellow in colour, and has a specific gravity of about 5. It occurs intimately mixed with pyrrhotite, and the nickel present in nickeliferous pyrrhotite is regarded as due to minute inclusions of pentlandite.

Nickeliferous pyrrhotite is highly magnetic. It is bronze-yellow or yellow in colour and has a specific gravity of about 4.5. It occurs in close association with basic igneous rocks, and, in deposits of economic value, it is usually associated with copper-pyrites, together with varying amounts of platinum and palladium.

Garnierite is a soft, earthy mineral, pale green to dark green in colour. Its specific gravity varies from 2.3 to 3. It occurs associated with serpentine, which is an alteration product of olivine rocks.

Niccolite, on account of its frequent association with cobalt and silver ores, is an important nickel mineral. It has a specific gravity of about 7.5 and is pale copper-red in colour.

In addition to the minerals mentioned, there are considerable amounts of nickel in nickeliferous iron-ores and blister copper.

The most important nickeliferous iron-ores have been formed by the laterization of masses of serpentine containing nickel and chromium. They cover extensive areas on the north coast of Cuba and they occur in deposits of economic importance in Greece and other countries, where they are mined, though not very successfully, for the manufacture of nickel-chromium steel.

An important source of nickel is blister copper. While the amount of nickel contained in copper ores varies considerably, there is no large quantity of blister copper refined that does not contain appreciable quantities of the metal. The blister copper obtained from the copper ores of the Katanga district in the Belgian Congo contains about 3 per cent. of cobalt and nickel, and considerable quantities of nickel are recovered in refining the blister copper obtained from the Hitachi mine in Japan. The greatest output of by-product nickel from the electrolytic refining of copper is, however, obtained in the United States, where up to one million tons of copper have been refined annually during recent years. The recoverable amount of nickel present in the blister copper refined in the United States is estimated at one

pound of nickel for every ton of copper treated. In the electrolytic refining of copper the nickel goes into solution in the electrolyte and is subsequently recovered as nickel sulphate, which is used in the nickel-plating industry or is reduced to metal.

With the exception of small quantities of chromium-nickel steel which are produced by the direct-smelting of the Cuban and other nickeliferous iron-ores, and a certain amount of ferro-nickel smelted from New Caledonian and other oxidized ores, the whole of the nickel ore smelted throughout the world is reduced in blast or reverberatory furnaces to a low-grade ferruginous matte containing, in the case of the sulphide ores of Sudbury, Canada, about 25 per cent. of nickel and copper. When oxidized ores are used and there is no copper present in the ore, the matte contains as a rule about 40 to 45 per cent. of nickel. The ferruginous matte is subsequently de-ferrated or bessemerized to remove as much of the iron and sulphur contents as possible without an excessive loss of nickel. The bessemerized matte from sulphide ores containing copper usually contains about 80 per cent. of nickel and copper, about 20 per cent. of sulphur, 0.5 per cent. of iron and small amounts of gold, silver, platinum and other metals of the platinum group. This matte is refined by either the Orford, the Mond, the Hybinette or other electrolytic process.

By the Mond and electrolytic processes all the precious metals contained in the matte can be recovered. In practice both methods recover a large proportion as a by-product, which is sold on the basis of its precious metal contents. By the Orford process a large part of the precious metals goes into the nickel and is lost, or into Monel metal when this is made.

During the process of roasting, smelting and refining the Sudbury sulphide ores, large quantities of sulphur dioxide are driven off. This gas is not at present utilized. Assuming the average sulphur content of the Sudbury ore to be 25 per cent., it is estimated that 420,000 tons of sulphurous acid gas are given off during the treatment of 1,000,000 tons of sulphide ore. This quantity is sufficient to produce 630,000 tons of sulphuric acid; but there is no market for sulphuric acid in that region, and the acid cannot be transported economically over long distances.

The Sudbury ores contain about 40 per cent. of iron. In every million tons of ore treated, 400,000 tons of iron, equal to one-half of the Canadian production of pig-iron, is slagged in the furnaces and lost. In view of the fact that about 60 to 70 per cent. of the nickel produced is used in the manufacture of nickel-steel, considerable attention has been given to the direct smelting of the Sudbury nickel-copper ores for the production of nickel steel. Recent improvements in roasting and desulphurizing methods have made it possible to remove the sulphur so completely that the roasted ore can be smelted to pig-iron having about double the nickel and copper contents of the original ore. It is claimed that copper can replace nickel to a considerable extent in a 3½ per cent. nickel steel without

detriment to the steel (Rept. Ont. Nickel Commission, 1917, p. 417).

In its condition as refined, the metal is not in a state capable of being rolled or forged, but if, when melted, it is de-oxidized as far as possible, it can be cast into extremely ductile and malleable ingots. Such ingots may be rolled or forged into sheets, rods, wire, tubes, etc., of practically any thickness that may be required. The malleability is greatly diminished by the presence of nickel oxide, carbon, sulphur, arsenic or silicon. In the cold rolled state the metal is hard enough to take a brilliant polish. When cast it has a specific gravity of 8·4 to 8·7, which is increased by rolling to as much as 8·9. Nickel is magnetic at ordinary temperatures, but it loses its magnetic properties at a temperature of about 350° C. The metal is particularly resistant to corrosion by alkalis; in acid solutions it is only slightly acted upon by hydrochloric and sulphuric acid, and not at all by salt or fresh water, but it is readily dissolved in nitric acid or aqua regia.

With the exception of the nickel obtained by the Mond process, which runs about 99·8 per cent., and is entirely free from cobalt, commercially pure nickel usually contains from 1 to 2 per cent. of impurities, namely, cobalt up to 1 per cent. and iron from 0·3 to 0·6 per cent., while a little copper, silicon, carbon, and magnesium are frequently present. Iron hardens nickel, and if more than 0·7 per cent. is present the metal is unsuitable for the manufacture of the best quality of nickel silver.

Metallic nickel is used for coinage purposes and for manufacture of cooking utensils and chemical apparatus and plant. It is also used for thermo-couple leads, sparking-plugs, thermionic valves, and glow-lamp tubes, etc. It is made into rolled or cast anodes for the electro-plating industry. When deposited electrolytically from nickel sulphate or nickel-ammonium sulphate, it produces a silver-like coating which strongly resists tarnishing on iron and steel goods as well as on brass, zinc and aluminium articles.

Nickel unites with copper to form a number of useful alloys.

A small addition of nickel, up to 3 per cent., is sufficient to harden copper and at the same time makes it better suited for exposure to high temperatures. By the addition of nickel, the red copper colour gradually disappears and the alloy becomes white after about 15 per cent. of nickel has been added. The copper-nickel alloys were formerly known as "nickel-bronze," but are now known as "copper-nickel," or in the case of the 80/20 alloy as "cupro-nickel."

The copper-nickel alloys mostly in use are: (1) 85/15 which is used in America; (2) 80/20 which is used for bullet jackets, &c.; (3) 75/25 which is used for coinage metal; (4) 60/40 which is used as a resistance metal, and which is remarkable for its exceedingly low temperature coefficient.

A similar alloy has lately been used for tableware.

The nickel-copper-zinc alloys, known as "nickel-silver" or "German-silver," contain about 50 to 65 per cent. of copper, 5 to 30 per cent. of nickel, and 18 to 30 per cent. of zinc. The

higher qualities are used for tableware without plating, while the lower qualities, which have a slightly yellow tint, are used for the same purpose for electro-plating.

Nickel enters into the composition of a number of alloys of high electrical resistance, and increasing attention is being given to the use of nickel as a constituent of alloys to be used as base metal thermo-couples in thermo-electric pyrometers.

An alloy of special interest to the nickel industry is Monel metal, which is made directly from roasted Sudbury matte. It contains about 68 per cent. of nickel, 30 per cent. of copper and about 1.5 per cent. of iron. In appearance it resembles pure nickel and it takes a brilliant polish. Monel metal is produced commercially in a variety of forms, but it is chiefly used in the form of rods, sheets and castings. It retains 80 per cent. of its tensile strength at 538° C.

As regards their tensile strength at high temperatures, however, the nickel-chromium alloys are superior to Monel metal. In recent years the alloys of nickel and chromium with or without iron have attained considerable importance. These alloys first came into use on account of their high electrical resistance and their long life when exposed to air at a high temperature, and in this connection have found extensive uses for electrical heating. In 1920 it was estimated that 500,000 kilowatts were employed on such electric heating in the United States and that, from 1906-1919, 2,000 tons of the nickel-chromium alloys had been used for this purpose. Typical alloys contain 85 per cent. Ni and 15 Cr, or 60 per cent. Ni, 12 Cr, 26 Fe and 2 Mn. More recently, castings of these alloys have been made in this country and abroad for heat-treatment boxes and other purposes where the strength of the material and its resistance to oxidation at high temperatures have proved invaluable. The alloy "Cronite," as manufactured in Great Britain, contains 60 per cent. of nickel and retains approximately 50 per cent. of its initial tensile strength of 30 to 32 tons per square inch at a temperature of 1,000° C.

In addition to the non-ferrous alloys mentioned, there are numerous other alloys of nickel, of which those containing aluminium would appear to be likely to attain commercial importance.

Nickel and iron combine in all proportions, and nickel steel is one of the most important products containing nickel. The term "nickel steel" is used not only for simple nickel-iron alloys, but is applied also to nickel-chromium steel and complex steels containing nickel and other metals such as vanadium, tungsten, molybdenum, etc.

The simple nickel steels, such as are largely used in the engineering industry, contain from 3 to 5 per cent. of nickel; besides these there is a considerable quantity of high-nickel steels made (more properly called ferro-nickel alloys) containing from 15 to 34 per cent. of nickel, a 25 per cent. alloy being the most com-

monly used. An alloy containing 34 per cent. of nickel is used in the manufacture of hair-springs for watches.

Nickel steels containing 3 to 4 per cent. of nickel and low in carbon are commonly produced by the open-hearth method. The nickel may be present in the original ore as is the case with the Cuban and Grecian nickeliferous iron-ores, or it may be added at any stage of the smelting or casting.

The tensile strength of nickel steels and nickel-iron alloys increases with the amount of nickel up to about 20 per cent. of the latter, but the most important nickel steel (apart from nickel-chromium steel) from an engineering standpoint is the low or medium carbon steel, commonly known as 3½ per cent. nickel steel, containing 0·5 to 0·8 per cent. of manganese.

During the war about 75 per cent. of the total nickel produced was utilized in the manufacture of nickel steels, but since then the consumption of the metal for this purpose has naturally diminished. In pre-war times the proportion was about one-half to two-thirds. Large quantities are now used for motor car and aeroplane parts and other engineering work where weight and bulk must be reduced to the lowest limit.

Nickel compounds have a variety of uses. The oxides are used in the pottery industry for colouring glazes and in glass manufacture. As a base for catalysts in the oil-hardening industry nickel sulphate or nickel nitrate is used in large quantities. Nickel sulphate is also largely employed in nickel plating, as also is nickel ammonium sulphate.

Nickel is also sold in the form of small cubes or in circular discs called "rondelles," as well as in cathodes, and in shot form and granules. Nickel pellets containing 99·8 per cent. of nickel, as made by the Mond Nickel Company, are recognized as being of the highest standard of purity.

In the year 1913 the price of nickel in the United Kingdom varied from about £165 to £170 per ton. During the war-period, in spite of the increased demand due to the war, the price of nickel remained fairly stationary, the rise in price being little more than sufficient to cover the increased costs of labour, freight and insurance. The highest average annual price realized in the United Kingdom during the period under review was £201 per ton in the year 1919.

### WORLD'S PRODUCTION

In the year 1913 the world's production of nickel, exclusive of by-product electrolytic nickel, was about 32,000 tons, of which output 69 per cent. was obtained from the nickel-copper and cobalt-silver-nickel deposits of Ontario, Canada, and about 25 per cent. from the oxidized ores of New Caledonia, the balance being obtained from Norway, Greece, Germany and other countries.

The nickel-copper ore deposits of Sudbury, Ontario, are much more extensive than those of any other country. The ores are rich and uniform in composition. The proved ore reserves in the Sudbury area are estimated at over 70 million tons, with probable reserves of another 80 million tons. There are, in

addition, large areas in this district which probably contain important ore-bodies, but they have not yet been proved, as the ore already developed is amply sufficient to supply present requirements. The nickel-mining and smelting industry is in strong hands, and the mines and metallurgical plants are equipped and operated in a highly efficient manner.

With the exception of a small amount of refined nickel obtained as a by-product in the treatment of cobalt ores, no nickel was refined in Canada before the year 1918, the whole of the matte produced being exported to South Wales and the United States for further treatment; but during the war-period, nickel-refining plants designed to produce about 16,700 tons of refined nickel per annum were established in Canada. The first of these plants commenced operations in the year 1918. During the war the increased demand by the Allied Powers for nickel for munition purposes was met wholly by increased production from the Sudbury area, the Canadian output rising to 41,298 tons in the year 1918. At the conclusion of hostilities there were large stocks of the metal available for industrial purposes and the output fell to 19,886 tons in the year 1919.

The larger part of the New Caledonian production of nickel has always been exported as ore and matte. As was to be expected with the restricted shipping facilities available during the period under review, the export of ore declined severely, and it amounted to only 1,536 tons in the year 1919. Considerable improvements and extensions have been made during the last few years in the smelting capacity of New Caledonia, and it is anticipated that ferro-nickel and ferro-chrome will be produced in the island before long.

The Norwegian production of nickel has always been small. It was largely increased during the earlier years of the war-period, when considerable amounts of refined nickel were exported to Germany. The smelting and refining capacity of Norway was increased to about 1,200 tons of metal annually, but the works were never run to their full capacity on account of lack of ore.

The German domestic production of nickel is obtained chiefly from the Frankenstein deposit in Silesia, a low-grade garnierite deposit containing about 2 per cent. of nickel, yielding before the war from 200 to 300 tons of nickel annually. In addition, a considerable amount of New Caledonian ore was smelted and refined there. At the outbreak of war there was in Silesia a stock of New Caledonian ore containing about 5,000 tons of nickel. This reserve, together with increased production from domestic deposits and largely increased imports of Norwegian refined nickel, was the chief source of German supplies during the war.

The United States does not produce nickel ore, but has always been the greatest refining centre of nickel metal, the raw material being imported chiefly from Canada in the form of nickel matte. During the war, when shipping for Europe was scarce and the usual markets were closed, increasing quantities of New Caledonian matte were imported by the United States, but these

shipments formed only a very small part of the total United States imports.

Nickel enters largely into the manufacture of war materials, and there was consequently an increased demand for refined nickel during the war-period. The United Kingdom more than doubled its peace-time requirements of about 3,670 tons, and both Italy and Japan imported large quantities of the metal. The United States output has been obtained chiefly from the International Nickel Company's refinery at Constable Hook, Bayonne, New Jersey, where in the year 1915 the plant consisted of five large nickel furnaces, 31 calcining furnaces and five nickel-refining furnaces, with additional copper blast and reverberatory furnaces and converters, the plant producing both nickel and copper for the market by the Orford process. It is understood that all the refining of matte by the International Nickel Co. (not including Monel metal) will in future be carried out at Port Colborne, Ontario, Canada.

The only other nickel-refining plant in the United States is situated at New Brunswick and treats chiefly New Caledonian matte.

*World's Production of Nickel Ore (in terms of metal)\**  
(long tons.)

	1913.	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.
Canada	22,177	20,321	30,495	37,035	37,647	41,298	19,886	27,382	8,613
Germany (Prussia)	267	248	330	1,634	2,039	1,841	574	59	
Greece	943	737	1,114	556	86	658	99	—	123
Norway	492	477	758	786	688	238	49	—	
Sweden	—	2	16	35	49	24	4	2,187	
New Caledonia (Exports)	8,098	7,780	5,316	3,996	4,687	2,666	1,780	456	326
United States†	215	378	734	820	359	394	99		

\* In addition to the outputs shown in this table, Tasmania produced 3,089 tons of copper-nickel ore (containing approximately 10 per cent. nickel and 4.5 per cent copper) during the years 1913 and 1914, and Egypt 74 and 229 tons of nickel ore in 1912 and 1914 respectively.

† Obtained as a by-product in the electrolytic refining of copper. Nickel, produced from copper-lead-cobalt-nickel ores mined in Missouri is included in 1919 and 1920.

## BRITISH EMPIRE

## United Kingdom\*

Small veins and pockets of nickel ore have been found in many of the tin-bearing lodes of Cornwall, and deposits of nickeliferous pyrrhotite containing up to 14 per cent. of nickel were formerly worked at Coillebhraghad and Craignure, both of which are situated not far from Inveraray in Scotland. Nickel ore is also found associated with haematite at Moel Hiraddug in the Cwm district of Flintshire, while at Darley Dale, in the Peak district of Derbyshire, nickel ore has been found encrusting the dolomite rocks; but none of these occurrences is worked and there is no production of nickel ore in the United Kingdom.

Nickel refining has long been an established industry in Great Britain. The chief works are those of the Mond Nickel Co. at Clydach and of the Anglo-French Co. at Hafod Isha, both near Swansea, in South Wales. The Clydach plant treats Canadian matte by the Mond refining process in which (1) the matte is roasted in order to drive off as much sulphur as possible, (2) the roasted matte is treated with sulphuric acid for the extraction of most of its copper contents as copper sulphate, followed by (3) the reduction of the residue to the metallic state by the action of water gas or producer gas rich in hydrogen, and (4) the volatilization of the nickel as nickel carbonyl by the action of carbon monoxide. The decomposition of the nickel carbonyl with deposition of metallic nickel completes the process. The Hafod Isha plant has a capacity of 3,500 to 4,000 tons of nickel annually; it refines only New Caledonian bessemerized matte, but it is equipped with Bessemer converters for treating low-grade matte, should it later be desirable to do so. Other works are those of Le Nickel Co. at Kirkintilloch in Scotland, and at Erdington near Birmingham. The Erdington works produce only metallic nickel, which is sold locally to the manufacturers of nickel alloys. The Kirkintilloch plant smelts and de-ferrates New Caledonian ores and matte as well as occasional shipments of nickel ore from other countries, the bessemerized matte produced being sold chiefly to the Hafod Isha and Erdington refiners, who produce the metal.

In addition to the nickel produced in domestic refineries, the United Kingdom before the war imported large quantities of the metal from the United States. In the year 1913 these imports were about 3,670 tons, and they were rapidly increased during the war-period. In the years 1915, 1916 and 1917, about one-half of the total exports of nickel from the United States was shipped to the United Kingdom. With the cessation of hostilities the demand for nickel greatly diminished. There were large stocks of the metal in hand, and imports from the United States in the year 1919 fell to the low level of 333 tons.

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\* Mem. Geol. Surv. Scotland, Special Reports on the Mineral Resources of Great Britain, vol. 17, 1921. Report of the Royal Ontario Nickel Commission; Toronto, 1917, p. 471.

### Rhodesia\*

Nickel ores occur at many places in Rhodesia, but so far no deposits of economic value have been found. Garnierite has been recorded from the Mashaba asbestos field and from Gwanda, and carbonate of nickel is known to occur in the Great Dyke, south of Lalapanzi.

### Union of South Africa†

Nickel ores have been found at several widely separated localities within the Union of South Africa, and during the last few years considerable efforts have been made to exploit the nickel deposits in the Insizwa Range between East Griqualand and Pondoland. The nickel occurrences in this region occur in close association with intrusive sheets of norite. These cover a wide area and have a thickness of about 2,000 to 3,000 feet. The important ore-minerals are pyrrhotite, chalcopyrite and pentlandite; niccolite and bornite occur sparingly, while gold, silver, platinum and palladium are usually present in small quantities.

Within the intrusives the sulphides of nickel, copper and iron occur disseminated throughout a mineralized zone at or near the contact of the norites with the underlying altered shales, or are found filling the many small fissures which traverse them.

Work in this region has hitherto been confined to prospecting the small fissure-veins in which the percentage of metal in the ore varies from 1·5 to 20 per cent. of copper and 1·5 to 10 per cent. of nickel, the average content being about 4 per cent. of each. Platinum is very irregularly distributed, occasional samples of the ore assaying as high as several ounces per ton, but the average platinum value may be taken at about 2 to 3 dwt. per ton. Gold and silver are present only in very small amounts.

Nickeliferous pyrrhotite and chalcopyrite also occur as irregular impregnations in the basic rocks which cover an area of about 5,000 square miles in the central Transvaal. Very little is known about these nickel-bearing deposits, as prospecting operations have been confined to the sinking of four shafts near Vlakfontein in the Rustenburg district. None of these shafts has penetrated below the permanent water-level into the zone unaffected by surface leaching. Samples taken from the lowest depth reached (95 feet) gave an average value of 2 per cent. of nickel and 0·7 per cent. of copper. Small quantities of gold, silver, and the metals of the platinum group are associated with the ore.

In the year 1919 a deposit of nickel ore was discovered on the property of the Scotia talc mine, in the Barberton district, eastern Transvaal. Prospecting operations have disclosed a bedded deposit about 2 feet in thickness containing, where sampled, from 17·2 to 25·8 per cent. of nickel. So far the owners have not developed this deposit.

\* Report of the Rhodesia Resources Committee, 1921.

† The Economic Geology of the Insizwa Range, by W. H. Goodchild; Trans. Inst. Min. Met., 1916-17, vol. 26, pp. 12-84. Nickel, by T. G. Trevor; S. Afr. Journ. Ind., 1918, 1, No. 15, 1385, and 1920, 3, No. 6, 532.

Nickel ores have also been found in the Transvaal at Derde Gelid, near Lydenburg; at Blaauwbank, near Waterberg; and at the Cobalt mines, Kruis River, North Middelburg.

Nickel in the form of garnierite is widely distributed in the serpentine rocks of the N'kandhla district on the south bank of the Umhlatuzi river, Zululand, but no attempt has yet been made to exploit these deposits.

### Canada\*

The proved deposits of nickel ore in Canada are estimated to contain about 2,000,000 tons of nickel, and there are in addition large reserves at present undeveloped. Practically the whole of the Canadian output, which in the year 1918 constituted about 88 per cent. of the world's production, is obtained from the Sudbury district of Ontario, only a relatively small amount being obtained from the Alexo mine, near Porcupine, and from the Cobalt district.

Before the war the demand for nickel was steadily increasing, on account of the increasing use of nickel steel for structural and engineering purposes. During the war still larger amounts were required, and the nickel-mining and smelting industry made remarkable progress. In spite of labour and other difficulties, the output of nickel during the year 1918 showed an increase of 86 per cent. over the 1913 figure, this constituting a record. Following upon the close of the war the output of nickel was greatly curtailed, and production in the year 1919 fell to a figure considerably below that of 1913.

In the Sudbury region the nickel-bearing ores occur generally as roughly lenticular segregations varying in width from a few feet up to 180 feet, with a length ranging from 100 feet to 1,000 feet or more. They are always associated with an extensive series of norite and micropegmatite rocks. These Sudbury nickel-bearing eruptives form a basin-shaped sheet which covers an area of more than 550 square miles. The longer axis of the basin extends from the Whistle mine in the township of Norman on the north-east, to the Sultana mine in Trill township on the south-west, a distance of 36 miles. The greatest width of the basin is 16 miles. Only the upturned edges of the sheet are exposed, and the known deposits are all either along the outer edge of the basin or on off-sets from it. The most productive section follows the southern rim from the Sultana mine to the Garson mine, in Garson township. Along this margin seventeen mines have produced nickel ore, and ten others have been worked on the different off-sets to the south of it. On the northern side the ore-deposits are more irregular and they are separated by wide stretches of barren ground. This area is, moreover, poorly supplied with railway communications, a deficiency which has

\* The Nickel and Copper Deposits of Sudbury, Ontario, by A. E. Barlow; Ann. Rept. Geol. Surv. Canada, 1890-91, pp. 122S-143S (reprinted in 1907). Report of the Royal Ontario Nickel Commission, Toronto, 1917. The Nickel Industry, by A. P. Coleman; Dept. of Mines, Canada, 1913. Ann. Repts. on the Mineral Production of Canada. Ann. Repts. of the Trade of Canada.

greatly hindered development. The known ore-deposits on the western rim are not important, and those on the eastern side are too difficult of access to admit of profitable mining at present. The ore-bodies of commercial importance are seldom found within the norite itself. They occur almost wholly in the rocks adjacent to the norite as mineralized dykes and off-sets. Many of the most productive off-sets have a cylindrical shape, the diameters of the pipes varying from 50 to 200 feet. They descend almost vertically and have been followed down for more than 1,400 feet, and it seems not improbable that they will continue to the greatest depth possible for mining.

The Sudbury ore consists almost wholly of pyrrhotite, chalcopyrite and pentlandite in a gangue of crush-conglomerates and breccias. Secondary nickel minerals are rarely found. Quartz is frequently abundant. Gold, silver, platinum and palladium are usually present in the ore in small amounts, and pyrite, magnetite, galena, zinc-blende and molybdenite are found in veins which cut the ore-bodies at several of the mines. The ore mined in the Sudbury district varies considerably in richness, the average metal content being about 2 to 3 per cent. of nickel,  $1\frac{1}{2}$  to 2 per cent. of copper, and 45 per cent. of iron. Cobalt, gold, silver, platinum and palladium are nearly always present in very small quantities. The greater part of the ore mined requires merely careful sorting to prepare it for the smelter. The amount of waste rock that can be removed by hand-picking varies from 10 to 16 per cent. on the Creighton mine and up to 60 per cent. on the Worthington. Even after cleaning, the ore still contains from 14 to 35 per cent. of silica.

The metallurgical processes consist of a preliminary roasting to remove part of the sulphur, followed by smelting in water-jacket furnaces to produce furnace or standard matte. The British America plant, however, will treat unroasted ore. The standard matte is re-smelted in converters to make a de-ferrated or bessemerized matte containing from 75 to 80 per cent. of nickel and copper. The final operation consists of separating and refining the nickel and copper and the extraction of the contained precious metals.

In the year 1913 there were only two companies operating in the Sudbury district, namely, the Canadian Copper Company, a subsidiary to the International Nickel Company of the United States, and the Mond Nickel Company, Ltd., an English concern. These two companies operated mines and smelters in Sudbury, the matte produced being shipped to the United States and to Wales for refining. In the year mentioned the British America Nickel Corporation, Ltd., was incorporated in Canada.

Remarkable changes were witnessed in the Canadian nickel industry during the period under review. The tendency in the mineral industry of Ontario is to produce as far as possible the finished article instead of merely mining and selling the raw ore. In 1916, the International Nickel Company of Canada, a subsidiary to the International Nickel Company, was formed for the

purpose of refining Canadian nickel matte in Canada. The company commenced the construction of a large nickel refinery at Port Colborne, Ontario, which is designed to produce about 7,500 tons of refined nickel and 4,000 tons of copper annually. The plant was completed and commenced operations in June, 1918. In the same year the company acquired the whole of the mines and works of the Canadian Copper Company. The British America Nickel Corporation did not produce any nickel matte or refined nickel during the period under review, but was engaged in developing its mines and in erecting a smelter at Nickelton, and a large nickel-refining plant at Deschenes on the Quebec side of the Ottawa river where cheap hydro-electric power is available. The plant is designed to produce about 7,500 tons of nickel and 4,500 tons of copper per annum by the Hybinette electrolytic process. The smelter has a capacity of 1,000 tons of ore and flux per day and is constructed for the direct smelting of the ore without preliminary roasting.

The nickel mattes produced at Sudbury differ considerably in the proportions of nickel and copper which they contain. The product of the International Nickel Company averages about 54 to 56 per cent. of nickel and about 24 per cent. of copper, while that of the Mond Nickel Company contains about 41 per cent. of nickel and about 41 per cent. of copper. The whole of the copper and nickel contents of these mattes is not produced as fine metal. In the case of the International Nickel Company, a considerable quantity of Monel metal is extracted without separation of the metals; while the copper contents of the Mond Company's matte are recovered during the refining operations in Wales in the form of copper sulphate, which is largely used in the vineyards of France and Southern Europe.

The only known nickel deposit of importance outside the Sudbury area is that of the Alexo mine in the township of Dundonald, in the Porcupine area. The Alexo ore-body is a contact deposit, the parent formation being serpentine. The ore is a mixture of nickeliferous pyrrhotite and chalcopyrite. The mine has been a small but steady producer throughout the period under review, the output being sent to the Mond Nickel Company's smelter at Coniston to be smelted.

Other occurrences of nickel ore are known in the townships of McCart, Munro, Strathy, and near Lake Shebandowan in the district of Thunder Bay, Ontario, and nickeliferous pyrrhotite associated with copper ore occurs in the Gabbro Copper Mines, Vancouver Island, British Columbia.

In addition to the metal recovered directly from nickel-bearing ores, a small amount of metallic nickel is obtained from the silver-cobalt-nickel ores of Cobalt. Previous to 1915 the nickel produced in the silver refineries was in the form of speiss, nickel oxide and nickel sulphate, but since that year nickel has been produced as metal in the form of shot assaying about 98 per cent. of nickel. This is sold chiefly to the manufacturers of platers' supplies and made into anodes.

Production of Nickel in the Sudbury District, Ontario.  
(long tons.)

	1913.	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.
Ore mined .....	697,944	893,182	1,217,900	1,398,512	1,356,056	1,465,729	511,071	1,014,100	
Ore smelted .....	735,181	844,568	1,135,967	1,358,651	1,297,912	1,392,761	673,721	969,785	
Bessemer matte produced .....	42,098	41,425	60,449	71,438	70,444	77,843	38,157	51,730	17,408
Copper content of matte .....	11,552	12,900	17,507	20,027	18,925	20,966	10,803	14,286	5,645
Nickel content of matte .....	22,177	20,321	30,392	36,874	37,398	40,969	10,746	27,283	8,596
Spot value of matte (£)* .....	1,474,364	1,497,715	2,156,738	2,524,236	2,500,863	1,376,413	†	†	

\* Values converted to £ sterling at the rate of 1 dollar = 4s. 2d.

† Not stated.

*Production of Nickel from the Silver-Cobalt-Nickel Smelters of Eastern Ontario*

Year.	Metallic Nickel.		Nickel Oxides.		Nickel contents of recoveries (long tons).
	Quantity (long tons).	Value* (£).	Quantity (long tons).	Value* (£).	
1913 ...	—	—	120†	6,275	§
1914 ...	—	—	175†	7,267	§
1915 ...	25	4,610	126‡	6,513	103
1916 ...	35	6,570	248†	21,116	161
1917 ...	119	22,570	294†	25,617	249
1918 ...	109	18,483	430†	44,849	329
1919 ...	178	28,632	152‡	6,846	212
1920 ...	91	14,851	11‡	1,315	99
1921 ...					

\* Values converted to £ sterling at the rate of 1 dollar = 4s. 2d.

† Excluding mixed oxides of cobalt and nickel.

‡ Including nickel sulphate.

§ Figures not available.

*Imports of Nickel, Nickel Silver and German Silver into Canada*

Year.	Nickel, Nickel Silver and German Silver in ingots or blocks.		Nickel, Nickel Silver and German Silver in bars, rods, strips, sheets and plates.		Manufactures of German, Nevada, and Nickel Silver, not plated.
	Quantity (long tons).	Value* (£).	Quantity (long tons).	Value* (£).	
1913 ...	19	3,064	245	30,795	18,057
1914 ...	32	5,284	245	27,097	17,330
1915 ...	33	5,700	284	35,376	16,154
1916 ...	80	13,857	318	53,919	18,559
1917 ...	136	25,828	246	51,119	31,191
1918 ...	43	8,186	242	41,583	42,543
1919 ...	34	6,242	289	44,246	71,471
1920 ...	3	679	325	52,771	118,955
1921 ...					

\* Values converted to £ sterling at the rate of 1 dollar = 4s. 2d.

*Imports of Nickel, Nickel Silver and German Silver, in ingots or blocks, into Canada*

Fiscal years ending March 31

20

From	Quantity (long tons).						Value* (£).
	1913.	1914.	1915.	1916.	1917.	1918.	
United Kingdom	...	11	9	—	6	90	1919.
United States	...	14	8	40	21	75	1920.
<b>TOTAL</b>	...	25	17	40	27	165	1921.
United Kingdom	...	1,832	1,475	—	1,192	16,049	7,337
United States	...	2,316	1,423	6,749	3,455	13,020	5,700
<b>TOTAL</b>	...	4,148	2,898	6,749	4,647	29,069	6,433

\* Values converted to £ sterling at the rate of 1 dollar = 4s. 2d.

*Imports of Nickel, Nickel Silver or German Silver in bars and rods, and also in strips, sheets or plates,  
into Canada*

Fiscal years ending March 31

From	Quantity (long tons).						Value* (£).
	1913.	1914.	1915.	1916.	1917.	1918.	
United Kingdom	...	7	2	—	324	288	—
United States	...	286	227	261	—	248	—
<b>Total</b>	...	293	229	261	324	290	—
						248	249
						—	260
						—	260
						—	338
						—	338
United Kingdom	...	1,138	293	25	—	517	—
United States	...	35,125	26,880	29,067	43,180	54,337	50,000
<b>Total</b>	...	36,285†	27,173	29,092	43,180	54,854	50,000
						—	39,634
						—	42,334
						—	42,334
						—	49
						—	52,858
						—	52,907

\* Values converted to £ sterling at the rate of 1 dollar = 4s. 2d.

† Including nickel valued at £22 imported from Austria-Hungary and Germany.

*Value of Imports of Nickel-Plated Ware into Canada*  
 Fiscal years ending March 31

From	Value* (£).							22
	1913.	1914.	1915.	1916.	1917.	1918.	1919.	
United Kingdom ...	19,879	28,922	16,699	8,912	9,891	6,402	3,650	9,610
Other British Possessions ...	30	1	1	—	—	113	9	—
Total from British Possessions ...	19,909	28,923	16,700	8,912	9,891	6,515	3,659	9,610
France ...	1,623	1,807	959	458	340	577	455	692
Germany ...	4,017	6,572	2,606	12	—	—	—	2,822
United States ...	276,677	257,043	161,676	149,254	231,955	247,086	228,124	327,760
Japan ...	6	14	37	31	404	1,380	2,344	1,316
Other Foreign Countries ...	366	487	300	52	29	7	3	215
Total from Foreign Countries ...	282,689	265,923	165,578	149,807	232,728	249,050	230,926	329,983
<b>TOTAL</b> ...	302,598	294,846	182,278	158,719	242,619	255,565	234,585	339,593
								384,505

\* Values converted to £ sterling at the rate of 1 dollar = 4s. 2d.

*Value of Imports of Manufactures of Nickel and Nickel Silver, not plated, into Canada*

Fiscal years ending March 31

From	Value* (£).					
	1913.	1914.	1915.	1916.	1917.	1918.
United Kingdom ...	3,848	4,841	3,907	1,816	1,460	1,600
New Zealand ...	...	—	2	—	—	—
Total from British Possessions ...	3,848	4,841	3,909	1,816	1,460	1,600
Austria-Hungary ...	244	565	165	—	—	—
Germany ...	139	137	179	—	—	—
United States ...	13,788	12,672	13,359	13,324	31,613	27,969
Other Foreign Countries ...	104	91	49	40	48	5
Total from Foreign Countries ...	14,275	13,465	13,752	13,364	31,661	27,974
<b>TOTAL</b> ... ...	18,123	18,306	17,661	15,180	33,121	29,574

\* Values converted to £ sterling at a rate of 1 dollar = 4s. 2d.

*Exports of Nickel from Canada†*

Year		Quantity (long tons)	Value* (£)
1913	...	22,080	1,082,408
1914	...	20,772	1,072,797
1915	...	29,648	1,540,510
1916	...	35,911	1,804,621
1917	...	36,282	1,814,302
1918	...	39,053	2,346,510
1919	...	18,311	1,682,832
1920	...	26,875	2,497,679
1921	...	5,741	646,448

\* Values converted to £ sterling at the rate of 1 dollar = 4s. 2d.

† Exports of nickel in ore and matte, and fine nickel.

*Exports of nickel (fine), and nickel contained in ore, matte or speiss from Canada (Domestic Produce)*

Fiscal years ending March 31.

\* Values converted to £ sterling at the rate of 1 dollar = 4s. 2d.

### Australia\*

Within the Commonwealth nickel-bearing deposits have been found in Queensland at Mount Coora, in the Kilkivan district; in the Annie mine at Cawarral; and at the Hector mine, near Rockhampton. These deposits consist of well-defined garnierite-bearing lodes in serpentine, but owing to their low nickel-content they have not received much attention. At Cawarral, the nickel is associated with chromium ores.

Nickel-bearing deposits also occur at Port Macquarie, Ewengar and Carcoar, in New South Wales. At Port Macquarie the ore is in the form of irregular masses and pockets either in serpentine or in clays resulting from the decomposition of this rock. Copper, cobalt, manganese, iron and chromium are present in small amounts.

Prospecting operations have disclosed a large body of nickel-bearing serpentine near Trial Harbour on the west coast of Tasmania, and nickel ores have been mined near Zeehan in the Dundas mining division. In this division, the nickel ore occurs in fissure veins which cut the slate formation near its contact with a mass of serpentine rock. The deposits are small, the largest being about 150 feet in length by about 4 to 5 feet in thickness. The ore minerals are chiefly nickeliferous pyrrhotite associated with copper and iron sulphides. The ore contains from 8 to 12 per cent. of nickel, with from 4 to 6 per cent. of copper, some silver and a little platinum.

The Dundas deposits were worked on a small scale before the war, the ore being shipped to Germany, Norway, and other countries. The total recorded output during the period under review was obtained in 1913 and 1914, when 3,089 tons of copper-nickel ore were produced, the metal content being approximately 10 per cent. nickel and 4·5 per cent. copper. Early in the war, the Federal Government placed an embargo on the export of this ore and, as there was no local market, production ceased.

The deposit at Trial Harbour occurs in a mass of serpentine which forms a hill about 300 feet in height. The chief nickel mineral is pentlandite, associated with magnetite and small quantities of pyrrhotite and garnierite. The ore occurs as segregations in small veins traversing the serpentine. Very little exploratory work has been done on this occurrence, which is remote from railway communications. Samples of ore taken from the workings and the waste heaps were found to contain from 1·9 to 18·6 per cent. of nickel.

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\* Tasmanian Nickel Deposits, by A. G. White; *Mining Mag.*, London, 1915 **12**, 103-5. The South Heemskirk Tin Field, by L. L. Waterhouse; Dept. Mines, Tasmania, *Geol. Surv. Bull.* No. 21, 1916, pp. 185, 214 and 415-421. Annual Reports of the Secretary for Mines, Tasmania. Queensland Industrial Minerals: Nickel, by B. Dunstan; *Queens. Govt. Min. Journ.*, 1921, **22**, 190-195 and 229-234.

### New Zealand\*

Nickel ores occur in many parts of New Zealand but no deposits of economic importance have been found. Nickel and cobalt minerals have been identified in the tailings at the Waitekauri gold mine in the Hauraki division, North Island, and the oxides of nickel and cobalt associated with manganese ore are not uncommon in the Waihi gold mines, where in places they form as much as 1 per cent. of the ore-body.

In the Dun mountain sub-division, South Island, there is a belt of serpentinized basic rocks which extends from D'Urville Island on the north to the Wairoa River, a distance of 55 miles. Within this region there are many small veins and lenses containing copper ores with which is associated much nickel-bearing pyrrhotite, but when tested the nickel content of the ore has been found too low to be of value.

Nickeliferous iron-ores have been reported from the Red Hill district in the west of Otago, but this occurrence has not so far been adequately prospected.

## FOREIGN COUNTRIES

### Austria†

A deposit of nickel ore was reported during the war period as occurring at the Nöckelberg pyrites mine near Saalfelden in Salzburg. The ore is found near the contact of shale and limestone, and occurs in both kinds of rock, but chiefly in the limestone. Analysis of a sample proved it to consist of a mixture of hydrated arsenates and sulphates of nickel and cobalt, together with hydrated iron oxide and various other constituents, notably lime and magnesia. It contained 8.28 per cent. of nickelous oxide and 1.41 per cent. of cobaltous oxide.

### Belgium

Belgium is not a producer of nickel ore. There is, however, an important nickel reduction plant at Antwerp, where New Caledonian ore and matte are further treated to produce a high-grade matte. The works are owned by La Société des Hauts-Fourneaux de Nouméa, the ore and matte being imported from the company's mines and smelter in New Caledonia. Before the war the matte produced at the Antwerp works was shipped for refining to New Brunswick, United States, but during the war all their shipments from New Caledonia, chiefly low-grade matte, were sent direct to the New Brunswick plant for treatment. In the year 1913, 15,934 tons of ore and 2,954 tons of matte were imported into Belgium from New Caledonia.

\* New Zealand Dept. of Mines, Geol. Surv. Branch, Bull. 10, 12 and 15 (New Series).

† Zeits. f. prakt. Geol., 1917, vol. 25, p. 163.

### Czechoslovakia

The nickel resources of Czechoslovakia are unimportant. Small deposits of nickel-copper ore containing from 17 to 22 per cent. of nickel and 4 to 10 per cent. of copper have been mined at Dobsina in the province of Gömör, and nickel ores associated with those of silver, cobalt, lead and bismuth were formerly mined at Joachimsthal, Annaberg, Schneeberg, and other localities in the Bohemian Erzgebirge.

### France\*

The rich silver ores mined in the mountains of Chalanches, in the department of Isère, are associated with cobalt and nickel ores and various ores of antimony, lead and copper. Very little nickel, however, is now produced from the mines, and France is dependent upon New Caledonian ores and matte and imported refined nickel for her supplies.

Before the development of the Canadian nickel-copper deposits, France held through her New Caledonian possession the leading position as a producer of nickel ore, and she still remains an important producer of refined nickel. La Société Anonyme de Nickel is the chief nickel-smelting and refining company in France. The company owns smelting and refining works at Havre, and controls smelting and refining works at Kirkintilloch in Scotland, refining works at Erdington in England, and before the war, operated also at Iserlohn in Germany.

In addition to the domestic production France has imported large quantities of refined nickel and nickel oxide from the United States.

#### *Production of Nickel in France.*

Year						Quantity (long tons)
1913	...	...	...	...	...	1,476
1914	...	...	...	...	...	3,337
1915	...	...	...	...	...	2,124
1916	...	...	...	...	...	2,361
1917	...	...	...	...	...	1,887
1918	...	...	...	...	...	702
1919	...	...	...	...	...	
1920	...	...	...	...	...	
1921	...	...	...	...	...	

\* Statistique de l'Industrie Minérale en France et en Algérie (1914-1918). Le Commerce de la France (Annual).

French Imports and Exports of Nickel

29

Year.	Imports.						Exports.					
	Ore.			Matte or speiss.			Refined nickel.			Nickel alloys.		
	Quantity (long tons).	Value* (£).	Quantity (long tons).	Value* (£).	Quantity (long tons).	Value* (£).	Quantity (long tons).	Value* (£).	Quantity (long tons).	Value* (£).	Quantity (long tons).	Value* (£).
1913	10,128	24,720	1,133	115,040	2,348	381,880	502	62,600	1,800	182,920	728	111,720
1914	28,121	68,600	756	46,040	2,123	342,200	245	30,720	1,177	71,760	1,085	167,640
1915	18,699	57,000	203	13,200	3,585	584,080	41	6,120	6	400	30	152
1916	8,772	32,080	827	55,480	1,748	303,920	104	17,960	—	—	242	76
1917	5,069	32,960	—	—	1,850	433,600	242	52,600	—	—	35	5,880
1918	3,236	26,320	98	13,240	813	240,360	29	11,160	—	—	40	113
1919	10,184	82,800	404	54,240	1,155	390,800	49	17,720	—	—	48	15,880
1920	698	8,520	2,329	321,920	119	57,240	106	49,800	1	160	158	34,360
1921	—	—	1,319	177,040	248	91,440	92	34,040	295	39,560	307	98,360
												23,480

\* Values converted to £ sterling at the rate of 25 francs = £1.

NOTE.—In addition, 133 tons and 1 ton of ore were exported in 1913 and 1914 respectively, and 1 ton and 2 tons in 1920 and 1921.

### Germany\*

The larger part of the nickel consumed in Germany is imported in the form of refined metal. There are important nickel-refining works at Iserlohn in Westphalia, and smelting and refining works at Frankenstein in Silesia, where, in addition to smelting local and New Caledonian ores, crude New Caledonian matte is deferrated and refined. Before the war the estimated production of nickel in Germany from domestic ores was about 200 to 300 tons annually, and from 1,000 to 1,200 tons of refined nickel were produced from New Caledonian ores. During the war Germany greatly increased her production from domestic ores and relied chiefly on imports of Scandinavian nickel and small quantities of low-grade Turkish ore to augment her supplies.

The German production of nickel ore is obtained chiefly from the low-grade garnierite deposits mined at Frankenstein in Prussian Silesia, where the ore contains about 2 per cent. of nickel; also from the deposits of nickeliferous pyrrhotite at Sohland in Saxony, and at Horbach and Totmoos in the Grand Duchy of Baden where pyrrhotite containing 12 per cent. of nickel is reported. Small veins of nickel associated with the ores of cobalt, silver and other metals occur in the Black Forest, the Harz Mountains, the Saxon Erzgebirge, and near Schneeberg in Saxony. These deposits were formerly extensively mined, but they are not now of much commercial importance, although doubtless they contributed to the German domestic production of nickel during the war-period.

In addition to the nickel obtained by smelting and refining nickel ores and matte, Germany produces a relatively large amount of by-product nickel in her copper refineries. It is estimated that as much as 800 tons of nickel and cobalt have been obtained in a single year from blister copper imported from the Katanga district, Belgian Congo.

### Production of Nickel Ore in Prussia

Year.	Quantity (long tons).	Estimated metal content (long tons)	Value† (£).
1913 ...	13,347	267	14,673
1914 ...	12,375	248	12,056
1915 ...	16,499	330	16,652
1916 ...	81,711	1,634	62,932
1917 ...	101,954	2,039	106,811
1918 ...	92,051	1,841	153,785
1919 ...	28,682	574	76,169
1920 ...			
1921 ...			

\* Zeits. f. d. Berg- Hütten- u. Salinenwesen.

† Values converted to £ sterling at the rate of 20 marks = £1.

### Greece\*

Chromiferous iron-ores containing from 0·10 to 1·2 per cent. of nickel and cobalt occur associated with the serpentine rocks that cover a large area in Greece and many of the adjacent islands. These ores are mined on an extensive scale in the district of Locris, on the mainland of Greece opposite the island of Euboea; in the neighbourhood of Thebes; near Tsouka, a village 9 miles north-west of the port of Larmes; at Karditza, 5 miles south-west of Thebes; and at Lutzi, 5 miles west of Tsouka. Chromiferous iron-ores occur at many other localities, but they are often too impure to be of economic value.

In the Thebes and Locris deposits, garnierite occurs in irregular stringers and pockets in the serpentine on the footwall of the chromiferous iron-ore. The dry nickel ore contains from 4 to 5½ per cent. of nickel, but owing to the irregular character of the deposits it is not possible to obtain an accurate estimate of the available tonnage of nickel. Before the war considerable quantities of this ore were shipped to Norway for reduction to metal. The mines continued working during the war, but their output was irregular and gradually declined, only 1,078 tons being raised in the year 1919.

#### *Production and Sales of Nickel Ore in Greece*

Year.	Production.		Sales.	
	Quantity (long tons).	Metal content (long tons).	Quantity (long tons).	Value† (£).
1913 ...	17,144	943	16,152	24,619
1914 ...	13,407	737	10,840	17,950
1915 ...	20,246	1,114	6,750	10,186
1916 ...	10,102	556	13,196	21,645
1917 ...	1,572	86	10,083	15,797
1918 ...	11,970	658	5,014	11,130
1919 ...	1,078	59	—	—
1920 ...	—	—	—	—
1921 ...	—	—	—	—

### Jugoslavia

No important deposits of nickel ore are as yet known in Jugoslavia. Millerite (nickel sulphide) is found associated with galena in the Mount Avala mines, 12 miles south of Belgrade, and small quantities of nickel sulphide occur associated with zinc ores at the Zavlaka zinc mines, 15 miles east of Loznitsa in western Serbia. Nickel sulphide has also been reported from Sadyevats near Ivanjitsa, 24 miles south of Chachak in southern Serbia.

\* The Chromiferous Iron-ores of Greece and their Utilization, by H. K. Scott; Journ. Iron and Steel Inst., 1913, 87, 447. Tableaux Statistiques du Mouvement Minier de la Grèce (Annual).

† Values converted to £ sterling at the rate of 25 francs = £1.

### Norway\*

Before the exploitation of the New Caledonian and Canadian nickel deposits the world was dependent chiefly upon the Norwegian nickel mines for its supply of nickel. The Norwegian nickel deposits are small, however, and the ore contains only a low percentage of nickel. The mines were unable to compete with the Canadian product, and the greater number closed down. The introduction of the Hybinette electrolytic process of refining in the year 1910 caused a considerable revival in the Norwegian nickel industry, which was further greatly stimulated by the increased demand for nickel during the war. Many abandoned mines were re-opened and worked, and the smelting and refining capacity of the country increased to 1,200 tons of nickel per annum. Since the war, all the Norwegian mines have been closed down.

Although 40 outcrops of nickel ore are known in Norway, the number of producing mines is small. The mines which furnished the bulk of the Norwegian ore were the Flaad at Evje; the Senjen in Tromsö; the Ringerike at Hole, Buskerud county; the Dambler and the Kragerö. The Dambler is a newly-opened mine, and is provided with its own smelter, while the others shipped their ore to the Evje, Ringerike and Stavanger smelters, the matte produced having been refined in a central refinery at Kristianssand, and the metal obtained going chiefly to Germany. The average recovery of metals from the ore is about 1 per cent. of nickel, 0.7 per cent. of copper, and  $\frac{1}{8}$  oz. of the precious metals per ton, of which silver constitutes about 95 per cent., the balance being palladium, platinum, and gold in the order named.

The nickel ore-deposits occur in close association with basic eruptive rocks and are similar in character to those at Sudbury, in Canada. Few of the deposits exceed 600 feet in length, and they have an average thickness of 10 feet. The ore minerals are pyrrhotite and chalcocite.

#### Norwegian Production and Exports of Nickel

Year.	Production.				Exports.	
	Ore.		Metal.		Metal.	
	Quantity (long tons).	Value† (£).	Quantity (long tons).	Value† (£).	Quantity (long tons).	Value† (£).
1913 ...	49,187	26,720	679‡	101,613	584	99,070
1914 ...	47,749	26,183	781‡	117,204	685	102,962
1915 ...	75,780	54,301	878	191,398	749	163,624
1916 ...	78,619	70,430	795	195,430	711	209,774
1917 ...	68,815	120,968	373	142,473	435	166,489
1918 ...	23,762	25,806	32	86,022	58	—
1919 ...	9,888	13,441	218	59,677	—	—
1920 ...	12,281	16,075	415	100,108	52	—
1921 ...					269	—

\* Norges Bergverksdrift (Annual). Norges Handel (Annual).

† Values converted to £ sterling at the rate of Kr. 18.6 = £1.

‡ Includes nickel obtained from Tasmanian, Grecian and New Caledonian ores.

### Russia

Low-grade nickel ores, chiefly garnierite, are mined in the Ekaterinburg district of the Urals, the ore being smelted at the Redwinsk works.

There are several deposits of cobalt and nickel ore in the province of Elisavetpol, in the Caucasus, but the nickel content of the ore is too low to allow of profitable extraction, and only the cobalt minerals are mined.

### Spain\*

Niccolite and garnierite were formerly mined on a small scale in the Jarales district, near Carratraca in the province of Malaga. The ores occur in serpentine in small veins and lenses which are seldom more than a few feet in length and 4 to 5 inches in thickness. They are said to contain from 1 to 20 per cent. of nickel. Farther to the south, near the Guadalmausa River, nickeliferous pyrrhotite associated with chalcopyrite occurs in small veins and masses in the serpentine rocks of the district. None of these occurrences is now being worked.

### Sweden†

The nickel deposits of Sweden are similar in character to those of Norway. During the war, many of the old mines, which could not previously be worked in competition with Canadian mines, were re-opened, and nickel-smelting works were established at Klefva, near Hvetlanda; in Småland and at Kusa in Dalarne. The chief deposits are situated at Sågmyra near Falun; at Klefva near Hvetlanda; at Frustuna in Södermanland; at Haddebo near the north end of Lake Vättern; and at Ruda, south-west of Oskarshamn.

The output of nickel was small and not sufficient to satisfy the domestic demand.

#### *Production of Nickel Ore in Sweden.*

Year.	Quantity (long tons).	Estimated metal content (long tons).	Value‡ (£)
1913 ... ... ...	—	—	—
1914 ... ... ...	153	2	742
1915 ... ... ...	1,616	16	2,699
1916 ... ... ...	3,504	35	12,440
1917 ... ... ...	4,911	49	7,352
1918 ... ... ...	2,440	24	21,546
1919 ... ... ...	409	4	1,164
1920 ... ... ...	—	—	—
1921 ... ... ...	—	—	—

\* Notes on the Ore Deposits of the Malaga Serpentines, by F. Gillman; Trans. Inst. Min. Met., 1895-1896, 4, 159-168.

† Admiralty Handbook of Norway and Sweden, H.M. Stationery Office, London. Bergshantering Berättelse av Kommerskollegium (Annual). Statistisk Årsbok för Sverige (Annual).

‡ Values converted to £ sterling at the rate of Kr. 18·2=£1.

*Imports and Exports of Nickel into and from Sweden*

Year.	Imports.		Exports.	
	Quantity (long tons).	Value* (£).	Quantity (long tons).	Value* (£).
1913 ... ... ...	135	22,543	1	125
1914 ... ... ...	129	23,697	0.4	95
1915 ... ... ...	496	116,850	69	24,911
1916 ... ... ...	123	30,918	30	23,439
1917 ... ... ...	40	21,511	8	7,065
1918 ... ... ...	58	51,161	4	4,122
1919 ... ... ...	57	14,911	1	305
1920 ... ... ...	141	31,110	—	11
1921 ... ... ...				

**Turkey†**

Deposits of low-grade nickel ore occur at Ak-Kaya in the vilayet of Castamuni, 31 miles north-east of Angora. During the war the total output of the mines was requisitioned by the Ministry of War, the mineral being shipped to steel-works in Germany and Austria. There are other deposits in the vilayet of Aidin.

**Egypt‡**

Nickel ore (garnierite) associated with nickel-bearing iron oxide occurs in the altered peridotite rocks of St. John's Island in the Red Sea. One deposit is known to be at least 150 feet in length, and from 2 to 5 feet in thickness. It has been proved to a depth of 120 feet. The garnierite ore contains about 9.48 per cent. of nickel and the iron oxide from 2 to 4 per cent. The ore is extremely friable, a characteristic which makes it difficult to separate the two minerals, the mixed ore averaging about 6.5 to 7 per cent. of nickel. Sufficient development work has not been done on these deposits to allow of an estimate being made of the quantity of ore available, but there are several thousands of tons of ore in sight.

The only outputs of nickel ore hitherto recorded are trial shipments of 74 tons in 1912 and 229 tons in 1914, which were sold in France.

**Madagascar§**

Nickel ores are known to occur in the ultra-basic rocks which cover extensive areas in the island of Madagascar. The chief deposits are situated in the district of Ambohimasoa, in the province of Fianarantsoa. In this area the basic rocks form a

\* Values converted to £ sterling at the rate of Kr. 18.2 = £1.

† The Minerals of Anatolia, by N. M. Penzer; Mining Mag., 1919, 21, 279.

‡ Report of the Royal Ontario Nickel Commission, Toronto, 1917, pp. 270-271.

§ Report of the Royal Ontario Nickel Commission, Toronto, 1917, pp. 276-277.

hill, more than 500 feet in height, which is penetrated to a depth of more than 60 feet by small veins and stringers of serpentine containing garnierite. Sufficient development has not been done to prove the value of these deposits, but at one of the groups of nickel mines it is estimated that there are 125,000 tons of ore available averaging 5.5 per cent. of nickel, with a probable further 250,000 tons containing 4 per cent.

### Cuba\*

Extensive deposits of nickeliferous iron-ore occur in the Mayari, Moa, and Cubitas or San Felipe districts of north-eastern Cuba. Mining operations are at present confined to the Mayari district, province of Oriente, where the ore occurs as a surface deposit about 19 feet in thickness which covers an area of 28,770 acres and contains about 605,000,000 tons of ore. Analyses of the dried ore give an average metal content of 48 to 49 per cent. iron, 1 per cent. nickel and 1 to 2 per cent. chromium. The deposit contains three distinct layers of iron ore, the content of nickel oxide increasing from 0.74 per cent. in the surface layer to 2.75 per cent. in the lowest layer, where it rests on serpentine. The ore is mined opencast by means of mechanical excavators. After sintering or nodulizing, it is shipped to the United States where, by a slight modification of the open-hearth process, it is smelted into nickel steel without the necessity of adding alloying elements in the furnace or ladle. This product, known as "Mayari steel," contains from 1.0 to 1.5 per cent. nickel, 0.2 to 0.75 per cent. chromium, less than 0.04 per cent. of sulphur, less than 0.03 per cent. of phosphorus, and whatever percentage of manganese is desired. The carbon range is from 0.03 to 1.50 per cent.

### Santo Domingo

Low-grade nickel ore occurs at the Perseverancia mine, Sierra Prieta, 19 miles north-west of San Domingo. Cuban capitalists are interested in the property and a considerable amount of surface development has been done. A line of railway has been surveyed from the mine to the Ozama river, 13 miles distant.

### United States†

Occurrences of nickel ore are widely distributed in the United States, under very diverse conditions, in the States of Missouri, California, Colorado, Connecticut, Idaho, Nevada, New Mexico, North Carolina, Oregon, Pennsylvania, Virginia and Washington. The deposits are small, however, and with the exception of the

\* The Mayari Iron Ore deposits, by J. F. Kemp; *Trans. Amer. Inst. Min. Eng.*, 1915, 51, 3-30.

† Report of the Royal Ontario Nickel Commission, 1917, pp. 267-270 and 411-413.

† Mineral Resources of the United States, Part 1 (Annual).

The Mineral Industry (Annual).

Foreign Commerce and Navigation of the U. S.

copper-lead-nickel deposit at Fredericktown, Missouri, none of them is now worked.

At Fredericktown the ore occurs in a bedded deposit at the contact of limestone and sandstone of Cambrian age. The average metal contents of the ore are about 2·5 per cent of copper, 2 per cent. lead, 0·8 per cent. nickel, 0·5 per cent. cobalt, and 0·5 oz. of silver to the ton. The mine is equipped with a concentrating mill having a capacity of 300 tons of rock per day, and from 85 to 95 per cent of the metals is recovered in the concentrates. Part of the lead ore separated in the mill is shipped directly to lead smelters, the remainder of the concentrates being reduced to matte in a blast-furnace. The copper is subsequently recovered by electrolytic refining, while the cobalt and nickel are recovered by chemical precipitation. The cobalt and nickel refineries commenced work in the year 1919, the nickel obtained being the first produced from domestic nickel ore in the United States for many years.

The United States has hitherto been the largest refiner of nickel, the raw material having been imported chiefly in the form of bessemerized copper-nickel matte from the International Nickel Company's mines and smelters in the Sudbury district, Ontario, and of unbessemerized matte imported from New Caledonia.

A development of much significance to the United States nickel-refining industry was the completion in the year 1918 of an important nickel refinery at Port Colborne, Ontario, where the Canadian matte formerly refined in the United States will in future be treated.

Before the war the larger part of the United States exports of nickel was shipped to Germany, the United Kingdom, the Netherlands and France. During the war large quantities of the metal were exported to Italy, Russia, France and Japan, while shipments to the United Kingdom were more than doubled.

*Nickel content of Nickel Salts, and Metallic Nickel produced in the United States as a by-product in the electrolytic refining of copper.*

Year	Quantity (long tons)			Value*	
1913	...	...	...	215	16,540
1914	...	...	...	378	65,208
1915	...	...	...	734	112,130
1916	...	...	...	820	139,832
1917	...	...	...	359	69,074
1918	...	...	...	394	83,542
1919†	...	...	...	456	90,518
1920†	...	...	...	326	61,094
1921	...	...	...	99	17,917

\* Values converted to £ sterling at the rate of 1 dollar = 4s. 2d.

† Including nickel produced from cobalt ores mined in Missouri.

Imports of Nickel Ore and Matte into the United States

37

From	...	Quantity (long tons).					1920.	1921.
		1915.	1916.	1917.	1918.	1919.		
Canada	...	38,503	55,395	58,854	56,995	20,321	29,627	1,407
Australia	...	976	2,457	2,199	2,088	2,686	—	—
Other British Possessions	...	—	—	—	437	—	—	—
Total from British Possessions	...	39,479	57,852	61,053	59,520	23,007	29,627	1,407
French Pacific Possessions	...	1,016	1,889	—	100	50	1,240	—
Other Foreign Countries	...	396	—	—	1	—	1,783	100
Total from Foreign Countries	...	1,412	1,889	—	101	50	3,023	100
TOTAL	...	40,891	59,741	61,053	59,621	23,057	32,630	1,507
Total Nickel content	...	25,253	32,416	33,710	32,676	13,082	18,565	912
						Value (£)*.		
Canada	...	1,457,796	1,879,579	1,903,957	2,286,318	1,041,177	1,609,016	81,271
Australia	...	45,362	105,733	98,626	90,391	168,518	—	—
Other British Possessions	...	—	—	—	17,938	—	—	—
Total from British Possessions	...	1,503,158	1,985,312	2,002,583	2,394,612	1,199,695	1,609,016	81,271
French Pacific Possessions	...	49,617	74,922	—	4,868	4,551	3,386	—
Other Foreign Countries	...	33,891	—	—	—	—	122,905	8,893
Total from Foreign Countries	...	83,508	74,922	—	4,877	4,551	164,291	8,893
TOTAL	...	1,586,666	2,060,234	2,002,583	2,399,489	1,204,246	1,763,397	90,164

\* Values converted to £ sterling at the rate of 1 dollar = 4s. 2d.

## *Nickel imported into the United States for Consumption*

From	1914.			1915.			1916.			1917.		
	Quantity (long tons).	Value* (£).	Quantity* (long tons).	Value* (£).								
Nickel, alloys, pigs, bars, etc.	...	...	47	8,891	15	2,824	13	1,639	33,710	4	160,421	160,421
Ore and matte (nickel content)	...	...	15,621	1,032,533	25,253	1,586,667	4	2,060,234	7	2,002,583	90,164	90,164
Nickel oxide	...	...	1	306	—	27	489	489	—	—	1,565	1,565
Nickel sheets and strips	...	...	...	5,880	—	1,345	—	1,020	—	—	—	—
All other manufactures of nickel	...	...	—	—	—	—	—	4,372	—	—	9,427	9,427
<b>TOTAL</b>	...	...	15,629	1,047,610	25,268	1,590,863	32,433	2,067,754	33,717	2,013,002	274,473	274,473
1918.			1919.			1920.			1921.			
Nickel, alloys, pigs, bars, etc.	...	...	—	2,459,489	2	3,240	531,965	3,083	456,928	1,038	160,421	160,421
Ore and matte (nickel content)	...	...	32,676	6	671	13,082	1,204,246	18,565	1,763,307	912	90,164	90,164
Nickel oxide	...	...	...	...	...	—	67	—	14	13	1,565	1,565
Nickel sheets and strips	...	...	3	1,433	—	5	1,019	—	—	—	—	—
All other manufactures of nickel	...	...	5	22,575	39	17,825	—	—	41,763	—	—	22,323
<b>TOTAL</b>	...	...	32,690	2,484,170	16,366	1,755,122	21,648	2,262,012	1,963	1,963	274,473	274,473

\* Values converted to £ sterling at the rate of 1 dollar = 4s. 2d.

Reports of Nickel, Nickel Oxide and Matte from the United States (Domestic Produce)

39

To	Fiscal years ending June 30					Calendar years.		
	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.
United Kingdom	3,396	7,800	6,289	7,074	4,911	334	31	
Other British Possessions	19	34	5	115	77	17	8	
Total to British Possessions	3,414	7,334	6,294	7,189	4,988	351	39	
Belgium	549	94	—	1,043	—	198	266	
France	1,973	1,433	855	521	—	601	33	
Germany	4,947	463	—	2,443	2,109	235	2	
Italy	670	1,056	840	226	—	26	—	
Netherlands	10	1,061	62	2,195	—	—	—	
Russia	83	2,458	2,946	140	13	6	6	
Sweden	—	164	138	267	129	396	260	
Japan	1	302	64	47	83	68	25	
Other Foreign Countries	...	...	...	...	...	...	...	
Total to Foreign Countries	9,486	5,880	5,157	6,653	3,413	1,350	504	
TOTAL	12,900	13,214	11,451	12,842	8,401	1,701	543	1190
United Kingdom	562,916	1,294,733	1,079,906	1,234,763	880,379	67,441	6,854	
Other British Possessions	3,357	6,147	1,037	2,939	17,322	2,749	1,828	
Total to British Possessions	566,273	1,290,880	1,081,003	1,256,802	87,701	70,240	8,177	
Belgium	98,995	16,542	—	203,610	139,513	46,051	58,201	
France	323,965	243,338	150,756	123,676	—	111,083	7,987	
Germany	626,322	58,854	—	48,859	432,875	—	518	
Italy	93,104	202,212	164,259	41,995	—	40,091	—	
Netherlands	175,066	1,836	12,510	398,088	—	4,668	—	
Russia	15,000	487,687	548,545	30,198	8,003	—	1,584	
Sweden	—	35,089	67,281	2,288	95,769	78,473	64	
Japan	112	27,389	13,102	18,212	14,244	6,469	34,329	
Other Foreign Countries	53,979	11,402	—	—	—	—	10,788	
Total to Foreign Countries	1,392,833	1,083,849	976,681	1,295,926	702,403	288,415	111,582	
TOTAL...	1,959,106	2,314,729	2,057,584	2,556,428	1,600,104	353,655	119,759	21,536

\* Values converted to £ sterling at the rate of 1 dollar=4s. 2d.

Value of Exports of Manufactures of Nickel from the United States (Domestic Produce)

40

To	Fiscal years ending June 30					Calendar years.		
	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.
United Kingdom	...	...	...	...	...	2,141	24,775	176,401
Canada	...	...	...	...	...	687	6,021	13,692
Australia	...	...	...	...	...	851	698	152,983
New Zealand	...	...	...	...	...	122	199	609
Other British Possessions	...	...	...	...	...	73	20	320
Total to British Possessions	...	...	...	...	...	3,874	31,713	192,070
Austria-Hungary	...	...	...	...	...	5,501	—	—
Denmark	...	...	...	...	...	—	154	2,255
France	...	...	...	...	...	—	1,648	109,646
Germany	...	...	...	...	...	9	—	—
Italy	...	...	...	...	...	4,289	16	—
Netherlands	...	...	...	...	...	—	48,932	75,029
Norway	...	...	...	...	...	—	—	33,793
Portugal	...	...	...	...	...	—	2,444	11,199
Russia	...	...	...	...	...	—	5,933	4,988
Cuba	...	...	...	...	...	—	—	15,869
Mexico	...	...	...	...	...	—	—	—
Salvador	...	...	...	...	...	150	157	31,106
Argentina	...	...	...	...	...	—	2,444	26,456
Brazil	...	...	...	...	...	—	5,933	11,199
Venezuela	...	...	...	...	...	—	—	7,936
China	...	...	...	...	...	93	86	—
Japan	...	...	...	...	...	—	1,959	1,563
Other Foreign Countries	...	...	...	...	...	60	224	425
Total to Foreign Countries	...	...	...	...	...	206	289	1,277
Total	...	...	...	...	...	6	71	3,156
						—	—	325
						—	73	6,564
						—	1,999	2,984
						447	6,876	6,405
						74	—	10,489
						10,851	70,895	347,575
						—	14,725	102,608
						—	14,725	539,645
						—	14,725	394,554
						—	14,725	148,843
						—	14,725	347,575
						—	14,725	115,126
						—	14,725	450,046
						—	14,725	311,641
						—	14,725	390,831
						—	14,725	392,946

\* Values converted to £ sterling at the rate of 1 dollar = 4s. 2d.

† Austria only.

### Brazil

Nickel ore containing from 3·5 to as much as 15 per cent. of nickel occurs as veins in serpentine in the vicinity of Villa de Livramento, in the State of Minas Geraes. Recent explorations in this region have indicated that important amounts of chrome ore are likely to be found associated with the nickel. Deposits of nickeliferous pyrrhotite are recorded at various localities in Minas Geraes, but these occurrences have never been worked.

### Peru

In the vicinity of the town of Rapi, in the province of Ayacucho, Peru, there are a number of small veins containing nickel, silver and cobalt ores in a gangue of quartz and calcite. These veins have been worked for silver only, the nickel minerals (chiefly niccolite) being discarded as not worth saving.

Veins containing niccolite associated with cobalt minerals, tetrahedrite and galena, occur in the Vilcabamba district, province of Cuzco, but the absence of railway facilities in this region prevents the exploitation of these deposits at the present time.

### New Caledonia\*

In New Caledonia the profitably workable nickel deposits are situated on the spurs of the main mountain ridge at elevations of from 400 to 2,500 feet. The parent rock is serpentine, the deposits being formed by the superficial weathering of the serpentine accompanied by a concentration of the nickel by the action of surface waters. The nickel mineral is garnierite, occurring partly as "green ore" and partly as "chocolate ore." Most of the ore now obtained is the chocolate variety, the colour being due to iron oxides.

The deposits are limited in area, the largest being about half-a-mile in length and comparatively narrow. As a rule they lie near the surface, the overburden varying in thickness from 1 foot to 20 feet. In some cases, however, they lie at a greater depth, but it is exceptional for any deposit to be worked where more than 20 feet of overburden has to be removed. The ore is obtained by opencast and quarrying methods, the broken rock after careful sorting being transported to the railway by aerial and surface tramways.

Before the discovery and exploitation of the Canadian nickel deposits in the year 1887, New Caledonia occupied the foremost position as a producer of nickel ore, but at the present time the output is comparatively small. The relatively small output is due chiefly to the character of the deposits and to the fact that they are scattered over a wide area. The largest known contain

\* Report of the Royal Ontario Nickel Commission, Toronto, 1917. The Nickel Industry, by A. P. Coleman; Canada Dept. Mines, Ottawa, Canada, 1913. Statistiques de l'Industrie Minière dans les Colonies Françaises (Annual).

only about 600,000 tons of ore, and very few of them contain as much as 250,000 tons. It has been estimated that the total reserves of ore, of the same grade as that now being mined (4·5 to 6·25 per cent. of nickel), contain not more than 160,000 tons of metal. Another factor that has hampered the expansion of the industry is the lack of refining facilities on the island. In the year 1913 about 91,700 tons of ore were exported, chiefly to smelting plants at Havre in France and Kirkintilloch in Scotland, each of which produced annually from 1,500 to 1,800 tons of nickel, while smaller amounts were sent to Antwerp in Belgium, also to the port of Rotterdam, in Holland, whence it was forwarded to Iserlohn, in Germany, for treatment. The shipping rates on these cargoes are very high. It has been estimated that in the year 1913 the freight rates charged on shipping nickel ore from New Caledonia to Europe were about equal to the cost of the ore loaded on board in New Caledonia, that is, the cost of the ore was doubled. As was to be expected, the exports of ore declined during the war period, and in 1919 amounted to only 1,536 tons, the whole of which, with the exception of a parcel of 51 tons consigned to the United Kingdom, was shipped to France.

In addition to the nickel ore exported, two companies have smelting works in New Caledonia. These plants are situated at Noumea and Thio, and each plant has a capacity of 100 to 120 tons of ore per day, producing about 9 tons of matte containing from 40 to 48 per cent. of nickel. At Tao there is an electric furnace which treats small quantities of ore. As the ore contains no sulphur, fluorspar and gypsum are required for fluxing, and these materials are obtained from Australia, local coral being used in the furnace-charge instead of limestone. During 1921 preparations were in hand for the erection of a large hydro-electric plant at Yate for the production of ferro-nickel and ferro-chromium. Before 1914 the matte obtained was exported chiefly to Belgium, the United Kingdom, France and Germany, but during the war the New Caledonian matte formerly sent to Antwerp and Germany was sent for refining to New Jersey, United States.

*Production of Nickel Ore in New Caledonia*

Year		Quantity (long tons)	Value* (£)
1913	...	161,764	151,258
1914	...	169,595	137,892
1915	...	138,722	107,146
1916	...	102,951	142,301
1917	...	93,725	243,855
1918	...	89,193	224,760
1919	...		
1920	...		
1921	...		

\* Values converted to £ sterling at the rate of 25 francs = £1.

*Exports of Nickel Ore† from New Caledonia*  
(long tons)

To	1913.	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.
United Kingdom	...	...	...	43,712	36,052	19,805	25,421	—	51
Australia	...	...	...	95	—	—	—	—	—
Total to British Possessions	...			43,807	36,052	19,805	25,421	—	51
Belgium	...	...	...	16,083	—	—	—	—	—
France	...	...	...	23,004	11,743	7,681	2,834	12,062	1,485
Germany	...	...	...	7,779	—	—	—	—	3,194
United States	...	...	...	—	—	2,699	3,223	3,298	—
Japan	...	...	...	—	—	—	—	—	—
Total to Foreign Countries	...			46,866	11,743	10,380	6,081	15,360	1,485
TOTAL	...	...		91,632	90,673	47,795	30,185	31,502	15,360
Total Value* (£)	...	...		114,345	112,961	62,509	68,277	100,263	46,031
									4,487
									9,452

† Average nickel content 6 per cent.

\* Values converted to £ sterling at the rate of 25 francs = £1.

*Exports of Nickel Matte† from New Caledonia*  
(long tons)

To	1913.	1914.	1915.	1916.	1917.	1918.	1919.	1920.	1921.
United Kingdom	...	...	1,476	2,483	590	787	953	—	—
Belgium	...	...	3,369	2,418	—	—	—	299	338
France	...	...	923	—	1,386	771	394	984	1,644
United States	...	...	—	300	3,463	3,297	4,868	3,480	2,468
Total to Foreign Countries...	...	4,292	2,718	4,849	4,068	5,262	3,874	3,751	4,436
<b>TOTAL</b>	...	5,768	5,201	5,439	4,855	6,215	3,874	3,751	4,436
Total Value* (£)	...	150,152	145,023	168,792	174,849	303,302	199,942	222,521	371,442

† Average nickel content 45 per cent.

\* Values converted to £ sterling at the rate of 25 francs = £1.

### Dutch East Indies

An extensive deposit of nickel-bearing iron ore occurs on Seboekoe, an island situated a few miles off the south-east coast of Borneo. The ore occurs as a surface deposit of limonite about 15 feet in thickness, and having a known length of four miles. Prospecting operations have shown that the deposits contain about 300,000,000 tons of limonite carrying about 0.5 per cent. of cobalt and nickel, 2.2 per cent. of chromium, and 52 per cent. of iron. The ore is similar in nature and origin to that containing nickel and chromium in Cuba.

Lateritic nickel-bearing iron ores have recently been discovered in the mountain ranges of central Celebes. These deposits are situated in the Verbeek Mountains, and are estimated to contain about 1,000 million tons of iron associated with 0.27 to 0.64 per cent. of nickel. In the vicinity of these deposits nickel ores occur as fissure fillings in the underlying serpentine. The nickel mineral is chiefly garnierite, and the percentage of nickel in the ore runs as high as 10 per cent. Prospecting operations have been carried out at Soroako on the southern shore of Lake Katano, and on Boetoh Hill near by. The average nickel value of the ore thus exposed varies from 2.5 to over 5 per cent. The nickel-bearing region has not yet been adequately examined, but the individual deposits appear to be small, few containing more than 50,000 to 60,000 tons of ore.

### China

An alloy of copper, nickel and zinc has been used for many centuries in China for the manufacture of gongs, candlesticks and various other articles. It is exported to Europe under the name of "packfong." Nickel is not produced separately in China, the alloy being obtained directly by smelting nickeliferous copper ores with those of zinc. These ores are obtained chiefly from the metalliferous districts of Yunnan and Szechuan in south-western China, but very little is known about the character of the deposits.

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